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Field Evaluation of a High Volume Surface Sampler for Pesticides in Floor Dust

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16. ABSTRACT House dust and the pollutants carried with it are potentially important contributors to total exposure through the pathways of ingestion, inhalation, and skin penetration, especially for small children. Pesticides may be one of the more important contaminants of house dust. This report describes a pilot study conducted in 9 homes in Jacksonville, Florida, which provides preliminary information on the pesticide content of floor dust. Both the questionnaire developed for the Nonoccupational Pesticide Exposure Study (NOPES) and a supplemental questionnaire were administered in each household to develop information on pesticide usage and other variables that might be related to the floor dust samples. All samples were collected from carpeted surfaces. The samples were analyzed for 33 pesticides by GC/ECD and GC/MS following the NOPES standard procedures. On average, 7 to 8 target pesticides were observed in the indoor air samples and 11 to 12 in the floor dust. The number observed in the floor dust ranged from 2 to 23. Thirteen of the pesticides were observed only in the floor dust. The most consistently observed pesticides were chlorpyrifos, with a median concentration of about 5 ppm in the dust, and chlordane, with a median concentration of approximately 6 ppm. Several pesticides that have not been in widespread use for many years were found. Exploratory statistical analyses suggest that a relationship may exist between the measured concentrations of pesticides in the dust and in the air for some pesticides. A relationship was observed between the number of pesticides detected and the age of the house.

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FIELD EVALUATION OF A HIGH VOLUME SURFACE SAMPLER FOR PESTICIDES IN FLOOR DUST

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FORWARD

Measurement and monitoring research efforts are designed to anticipate environmental problems, to support regulatory actions by developing an in-depth understanding of the nature and processes that affect health and the ecology, to provide innovative means of monitoring compliance with regulations, and to evaluate the effectiveness of health and environmental protection efforts through the monitoring of long-term trends. The Atmospheric Research and Exposure Assessment Laboratory, Research Triangle Park, North Carolina, has responsibility for assessment of environmental monitoring technology and systems, implementation of agency-wide quality assurance programs for air pollution measurement systems, and supplying technical support to other groups in the Agency, including the Office of Air and Radiation, the Office of Toxic Substances, and the Office of Solid Waste.

The determination of human exposure to toxic organic compounds is an area of increasing significance to EPA. The development of a new sampling methodology for a heretofore poorly understood media will permit important new information to be gathered so this potential route of exposure to these compounds can be properly evaluated.

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ABSTRACT

House dust and the pollutants carried with house dust are potentially important contributors to total exposure through the pathways of inhalation, ingestion and skin penetration, especially for small children. Pesticides may be one of the more important contaminants of house dust. This report describes a pilot study conducted as a part of the Non-Occupational Pesticide Exposure Study (NOPES) which provides preliminary information on the pesticide content of floor dust.

A high volume surface sampler (HVS2) for the collection of house dust and the semivolatile organics in house dust has been developed and tested in the laboratory. This study also served as a field test and initial validation study of the HVS2. The HVS2 is designed to collect more than 2 g of floor dust from a rug in an average clean residence in a few minutes. Such a large sample could be used in bioassays or analyzed for a variety of contaminants.

This study was conducted in nine houses in the Jacksonville, Florida Phase III segment of the NOPES study. Both the NOPES questionnaire and a supplemental questionnaire were administered in each household to develop information on pesticide usage and other variables that might be related to the floor dust samples. All samples were collected from carpeted surfaces.

The samples were collected and processed using previously published procedures. Both the HVS2 and the procedures were found to be generally satisfactory. An average of 3.2 m^2 (34 ft^2) was necessary to collect a 2 g sample. The total time for collecting a single sample, including sample processing, cleanup of the HVS2, and travel time, was approximately 4 hours.

The samples were analyzed for 33 pesticides by GC/ECD and GC/MS following the NOPES standard procedures. High concentrations of interfering compounds in some samples required substantial dilution before they could be analyzed. As a result, other analytes were diluted below their detection limit.

On average, 7.5 target pesticides were observed in the indoor air samples and 11.8 in the floor dust. The number observed in the floor dust ranged from 2 to 23. Thirteen of the pesticides were observed only in the floor dust. The most consistently observed pesticides were chlorpyrifos, with a median concentration of about 5 ppm in the dust, and chlordane, with a median concentration of approximately 6 ppm. The median surface loading of chlorpyrifos was approximately 6 ug/m^2, and of chlordane, about 13 ug/m^2. No significant correlation between surface loading and dust concentration was seen for these or most other pesticides. Several pesticides were observed in floor dust which have not been in widespread use for many years.

Exploratory statistical analyses suggest that a relationship may exist

between the measured concentrations of pesticides in the dust and in the air for some pesticides. A relationship was observed between the number of pesticides detected and the age of the house.

The HVS2's PUF plug adsorber was necessary for the accurate measurement of five pesticides. The source of the pesticides on the PUF plug (room air or blow off from the glass fiber filter) was not determined nor is it clear why these five pesticides are more likely to be found in the PUF plug. A supplemental experiment indicates a relationship between blowoff and vapor pressure.

This report is submitted in fulfillment of Purchase Order 92591 between Research Triangle Institute and Envirometrics, under Contract No. 68-02-4544 with the U.S. Environmental Protection Agency. This report covers the period from 1/26/88 through 9/24/88, and work was completed as of 9/24/88.

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SECTION 1

INTRODUCTION

The Non-Occupational Pesticide Exposure Study (NOPES) was designed to gather information on total human exposure to selected pesticides among persons not occupationally exposed, using the Total Exposure Assessment Methodology (see Wallace, 1987). During Phase I and Phase II of NOPES, measurements were taken to permit estimates of human exposure through air, drinking water, and dermal contact. This report describes a pilot study during the NOPES Phase III activities which provides preliminary information on possible human exposure to pesticides through the additional medium of household dust.

The importance of routes of exposure other than inhalation has been increasingly recognized in recent studies. The Health and Safety Plans for the Hyde Park disposal site in Niagara Falls, New York developed under a Superfund consent decree require the monitoring of homes for contamination of the house dust. However, prior to this study no validated procedure existed to make such measurements.

The ingestion of pollutants deposited on soil and dust (particularly house dust) is expected to be especially important for very young children, because of their lower body weight and frequent hand-to-mouth activity. The toddler has only about one-fifth the body weight of an adult and ingests an estimated 2.5 times as much dust, which increases the potential health risk to the child by at least 12 times. Their greater dermal contact with house dust and their larger surface to volume ratio may also be significatnt. Further, the risk to such children will be increased by the early stage of development of their organs, nervous system, and immune system. Estimates of the risks posed by pesticides and other semivolatile chemicals should therefore include an evaluation of the dust-mediated pathway.

A preliminary analysis of the potential routes of human exposure to chlordane (Budd, 1988) suggests that dust may indeed be an important pathway but that the relative importance between inhalation and ingestion of dust is difficult to determine with the data currently available. In particular, the expected contemporaneous concentrations in the air and dust media cannot be stated with any confidence. Some studies have found a correlation between air and dust concentrations for some pollutants under certain conditions, while these studies and others have observed, under other conditions, significant concentrations in the dust when the contaminant was not observed in the air. Additional contemporaneous measurements of air and dust concentrations are necessary to better define the importance of dust ingestion.

Validation of a method for sampling surface dust is necessary if reliable measurements are to be made. The study reported here also served as a field test and initial validation study of a new surface dust sampling

methodology, the High Volume Surface Sampler (HVS2), constructed by Cascade Stack Sampling Systems (CS3). The HVS2 was designed and developed (Roberts and Ruby, 1988) under EPA sponsorship as a way to collect removable surface dust accumulations on indoor surfaces (e.g., rugs and floors) and outdoor fugitive dust surfaces (e.g., bare ground at a contaminated-earth site).

The HVS2 has been extensively tested in the laboratory. It is designed to collect several grams of dust in a few minutes from a rug or bare floor in an average house. Such a large sample could be used in bioassays or analyzed for a variety of contaminants by separate techniques. Because many of the environmental pollutants of most concern in the dust matrix are semi-volatile organics, the HVS2 has been, and is here, carefully studied for its ability to capture these organic compounds.

This study involved nine houses in the Phase III Jacksonville NOPES set. The HVS2 was used to collect a sample of dust in each house. Analysis included the dust loading on the surface and the concentration of pesticides in the dust. The primary purposes of this study were to field test the HVS2 to validate the methodology, to obtain preliminary data on the amount and characteristics of dust in residences, and to obtain preliminary data on the species and concentration of pesticides in house dust.

This report provides information on the practical aspects of field operations with the HVS2, the ability of the HVS2 to retain the collected pesticide material, the variation in dust loading observed in the nine houses, the loading and concentrations of pesticides in house dust in the nine houses, and a comparison of the concentrations in the air and in the dust.

NOPES

The purpose of NOPES was to estimate human exposure to selected pesticides through air, food, drinking water, and dermal contact for statistically representative samples of populations in two urbanized areas in the United States. NOPES was conducted in the Jacksonville, Florida area and in the Springfield/Chicopee, Massachusetts area. Phase I sampling took place in Jacksonville in the summer of 1986. Phase II sampling occurred in both locations in the spring of 1987. Both locations were sampled again in the winter of 1988 as Phase III. A total of 173 separate households were sampled in the Jacksonville area and 86 in the Springfield/Chicopee area. Average household pesticide use is estimated to be relatively high in Jacksonville but moderate in Springfield/Chicopee. There is little agricultural pesticide use in either area.

In each sampled household both an indoor and an outdoor air sample was taken using a sampler essentially the same as that described in the standard sampling procedure for pesticides and polychlorinated biphenyls, TO4 (Riggin, Winberry, and Tilley, 1986). A personal air sample was collected using a personal sampler of the same design. In addition, two interviews were conducted exploring pesticide usage, eating patterns, and pesticides actually in the home. Tap water samples were collected in a subsample of houses and actual measurements were made of air and dermal (material collected on cotton gloves) exposures during specific pesticide application

TABLE 1. NOPES TARGET PESTICIDES

Compound	Uses
Aldrin	Subsurface termites; other uses discontinued 1971
Atrazine	Non-selective weed control
Bendiocarb (Ficam*)	Household, ornamental, turf insects
alpha-BHC	Insecticide; use discontinued 1978
gamma-BHC (Lindane*)	Seed treatment, fruit and vegetable insects
2,4-D	Postemergent weed control
Captan	Fungal control for seeds, vegetables
Carbaryl (Sevin*)	Lawn. ornamentals, vegetable, and pet insects
Chlordane	Termites; use discontinued April, 1988
Chlorothanlonil (Bravo*)	Broad spectrum fungicide
Chlorpyrifos (Dursban*)	Mosquitos, household insects, and lice
DDD	Metabolite of DDT; use discontinued 1971
DDE	Decay product of DDT and Dicofol
DDT	Broad spectrum insecticide; use discontinued 1971
Dacthal	Preemergent weed control
Diazinon	Soil and household insects
Dichlorvos (DDVP)	Flea collars and no-pest strips
Dicofol	Mites on fruit, vegetables, and ornamentals
Dieldrin	Subsurface termites; other uses discontinued 1971
Folpet	Fungal control on ornamentals and in paints
Heptachlor	Subsurface termites; use discontinued April 1988
Heptachlor epoxide	Oxidation product of Heptachlor
Hexachlorobenzene (HCB)	Bunt control on wheat and wood preservative
Malathion	Insects on fruit, vegetables, ornamentals
Methoxychlor	Insects on fruit, shade trees
ortho-Phenylphenol	Household disinfectant, postharvest fruit
Oxychlordane	Oxidation product of chlordane
Pentachlorophenol (PCP)	Exterior wood preservative, antimicrobial
cis-Permethrin	Flies, mosquitos, household and vegetable insects
trans-Permethrin	Flies, mosquitos, household and vegetable insects
Propoxur (Baygon*)	Flies, mosquitos, household insects
Resmethrin	Flies, mosquitos, household and pet insects
Ronnel	Flies, household insects

* Trademark

activities for a small number of participants. A limited number of houses were revisited in each of the phases in order to gain some information on the seasonal variation in air concentrations. Replicate samples were also collected. The air, water, and glove samples were analyzed for the 33 pesticides listed in Table 1.

Many of the pesticides studied in NOPES were found to occur at detectable levels in indoor residential air in both Jacksonville and Springfield /Chicopee. The concentrations (both indoor and outdoor) were generally higher in Jacksonville than in Springfield/Chicopee. Seasonal variations were observed, with summer concentrations being the highest. Detailed descriptions of the NOPES study procedures and data collected in Phase I have been provided by Lev-On et al. (1987), in Phase II by Immerman et al. (1988a), and in Phase III by Immerman et al. (1988b).

SECTION 2

CONCLUSIONS AND RECOMMENDATIONS

The use of the HVS2 in this nine-home pilot study has shown it to be an effective and efficient way to collect household floor dust samples of sufficient size to permit detailed chemical analysis. Experience with the HVS2 suggested some minor modifications to the device to make it more maneuverable. Additional study should be undertaken to determine the variability of recovery efficiency of the HVS2 with samples of real house dust. The operating procedures and sampling documentation were found to be workable and complete, although additional comments on the availability of a portable hood for use during cleanup should be added.

On average, a bulk sample of about 2 g could be collected in less than 7 minutes. This required an area of about 3.2 m^2 (34 ft^2). However, the conditions in homes vary widely; in one home more than the required amount of sample was collected in a few minutes and in another it took about 1.5 hours. In another home an apparently satisfactory sample did not yield a sufficient amount of the fine fraction after processing. The time required for sample collection could be reduced if the analytical method requires less than 2 g. The average total time required for collecting and processing a sample, including travel time to the sampling site, paperwork, preparation of the sample for shipping to the analytical lab, and cleanup and preparation for the next sample, was approximately 4 hours.

The procedure for separation of the fine particulate matter from the total cyclone catch should be examined to determine if processing to constant weight should be used instead of the current fixed processing time.

Analytical procedures were generally satisfactory. However, high concentrations of pesticides in some samples required substantial dilution before they could be analyzed. As a result, other analytes were diluted below their detection limit. A cleanup procedure should be developed for the cyclone catch that would remove interfering compounds, allowing accurate measurement of all the target compounds.

On average, 7.5 target pesticides were observed in the indoor air samples from each house. An average of 11.8 target pesticides were observed in the floor dust. The number of target pesticides in the floor dust ranged from 2 to 23. Thirteen of the pesticides were observed only in the dust. A summary of the median value (of the sites where that pesticide was observed) and maximum value for floor dust concentration (in ppm) and loading (in ug/m^2) of the most commonly observed pesticides is provided in Table 2. These data understate the total amount of pesticide present on the floor as the HVS2 does not recover all of the floor dust and only the fine fraction is retained and analyzed.

TABLE 2. SUMMARY OF DUST AND PESTICIDE DATA

	Median		Maximum	
Dust <150 um	1.2 g/m^2		169 g/m^2	
o-Phenylphenol	0.2 ug/m^2	1.3 ppm	8.7 ug/m^2	1.9 ppm
Propoxur	0.4	0.6	41.5	7.6
Diazinon	0.2	0.4	57.4	10.4
Heptachlor	0.3	0.1	14.7	9.9
Chlorpyrifos	5.6	4.7	193.7	21.9
Aldrin	0.3	0.3	11.3	1.0
Chlordane	12.9	6.3	183.9	98.6
DDE	0.5	0.3	0.6	1.2
Dieldrin	0.4	0.5	7.4	18.2
DDT	0.4	0.4	9.0	4.0

Several pesticides were observed that have not been in widespread use for many years. It is not known if these were long-lived residues from earlier indoor applications, recent applications of old pesticide material, or material tracked-in from outside areas which were treated in years past.

Duplicate samples were obtained at two sites. The samples were very similar in composition and amount.

A relationship was observed between the number of pesticides in the samples and the age of the house. No relationship was found with any of the other physical or socio-economic variables. A significant correlation was observed between surface loading (e.g., ug/m^2) and dust concentration (e.g., ppmb) for only two pesticides. For other pesticides the correlation coefficient was generally small as well as not significant.

When a pesticide was present in both the air and dust samples, simple statistical tests suggest, with a high degree of confidence, that a relationship may exist between the air concentration and the concentration in the dust for some pesticides. The sample size was not sufficient to quantify the relationship or to identify which pesticides could be so related.

A PUF plug was necessary for accurate measurement of alpha-BHC, HCB, gamma-BHC, heptachlor, and aldrin. The source of pesticides found on the PUF plug could be either the indoor air drawn through the HVS2 or pesticide material blown off the dust in the cyclone or on the quartz fiber filter. It was not possible to refute either alternative with the data available. A supplemental study did show that blowoff could occur over time and was a function of vapor pressure, especially over the short-term. Further study will be necessary to determine if the PUF plug, or a lower pressure drop alternative, is necessary to retain these pesticides and other semi-volatile compounds.

This work leaves a number of questions about household exposure to pesticides unanswered. Although this study has demonstrated the presence of a wide variety of pesticides in household dust in significant concentrations, it is not clear that this material presents any risk to residents. However, preliminary studies do suggest that the dust-mediated pathway may

be a significant route of exposure, especially for very young children. A series of studies should be conducted to determine the sources of these pesticides and the mechanism of transfer, if any, from the dust to residents. Specifically, 1) longitudinal studies should be made of pesticide application events, 2) studies should be made of surrounding soils to evaluate "track-in" as a source for the pesticide materials, and 3) studies of pesticide materials on residents, or dirt and surrogates on very young children, should be conducted to determine the amount and manner of transfer from house dust to residents.

SECTION 3

DATA COLLECTION METHODS

The sampling activities for this study were integrated with the NOPES Phase III sampling activities. Therefore the houses sampled were houses selected for the NOPES sampling, the survey of participants was administered with the NOPES survey, and the sampling occurred immediately following the NOPES sampling in that household.

Selection of Sample

The Jacksonville NOPES study area consisted of the 10 centrally located Census-defined County Divisions. The NOPES three-stage sampling procedure began with a stratification of the Census-defined Block Groups within these County Divisions according to socio-economic data. Six "first-stage sampling units" or areas were selected from each of four first-stage strata. Addresses were field verified and 2,438 housing units were eligible for the second-stage sampling, from which 550 houses were selected. Housing units were selected from respondents in this pool after a short, personal screening interview, which gathered information on the household members and on four characteristics potentially correlated with indoor pesticide levels: presence of pets that are treated for fleas or ticks, indoor application of pesticides to control insects, treatment of indoor plants with pesticides, and treatment of the housing unit with termiticides. The screening interview data permitted the housing units to be sorted into three classes of potential pesticide exposure, "high", "medium", and "low". Less than 21% of the households refused to participate in the screening interview.

A third-stage sample was selected from among the residents of second stage responding households. The third-stage sample was distributed across three classes of potential pesticide exposure, with the goal of 50% high, 30% medium, and 20% low exposure respondents. Selection at this stage was limited to family members over 16 years of age who were willing to participate in the survey interviews and to carry a personal sampler for 24 hours. A more detailed description of the NOPES sampling procedures is provided by Immerman et al. (1988a).

The houses for floor dust sampling were obtained opportunistically from volunteers in the third-stage sample during one week of routine sampling activity. Although the goal for the dust sampling was to have four houses in the "high" potential exposure class and four in the "low" class, the final set included seven in the "high" class and two in the "low" class. Time constraints on the sampling team prevented waiting for more "low" class houses to be identified. All of the houses sampled were among those newly selected for the Phase III study; none were among those repeated from a previous phase. One house with primarily bare wood floors was rejected.

In all but two houses the floor dust sampling took place on the day air sampling was concluded, beginning immediately after the sample was collected. In one of the houses (0966-021) the air sampling was finished the day before the dust sample was collected and in another (1440-016) air sampling was concluded two days earlier.

The selection of the floor area within the house to be sampled was determined primarily by convenience for sampling and the probability that a sufficiently large dust sample could be collected in a short period of time. For example, areas were chosen that did not require furniture to be moved in order to set up the rectangular sampling areas required by the procedure. No attempt was made to presurvey the entire house in order to select a representative area or an area where children would be likely to play. In one house an area was avoided because a canister of pesticide had been left sitting on the floor there the previous day (following the interview). All the samples in this study are from carpeted surfaces.

Participants Survey

The NOPES Study Questionnaire was administered in a personal interview at the same time 24-hour monitoring was initiated. At the end of the sampling period a 24-Hour Activity Log was administered to the respondent. The Study Questionnaire requested demographic data for the individual respondent, any occupational exposure to pesticides, the potential for pesticide use in the home, a detailed record of all food eaten during the previous 24 hours, and an inventory of all pesticides currently in the house. The Activity Log recorded any activities that might have involved pesticides, either by direct or indirect exposure, and the amount of time spent in various locations. Copies of the NOPES questionnaire and the activity log are reproduced in Immerman et al. (1988b).

In the floor dust sample houses an additional questionnaire was administered. This questionnaire included queries on the type and frequency of floor cleaning, the number of cigarettes smoked in the household, and the frequency of fireplace or woodstove use, if one were present. A copy of the supplemental questionnaire is provided in the appendix.

In addition, the sampling team recorded the type and approximate age of the rug, made a sketch of the precise location of the sample area, and recorded other comments about the house, participants, or sample site which might be relevant to the floor dust sample.

Sampling Equipment and Procedures

Floor dust sampling was carried out using the HVS2 and the sampling procedures described by Roberts and Ruby (1988). In brief, the HVS2 is a high-powered vacuum cleaner equipped with a nozzle that can be adjusted to a specific static pressure within the nozzle, a cyclone to separate the larger particles from the air stream immediately after their removal from the surface, a high efficiency quartz fiber filter for particles, and (optionally) a polyurethane foam (PUF) plug adsorber for semivolatile organic com-

pounds. The HVS2 samples at a flow rate of approximately 9.5 L/s (20 cfm), which can be regulated and is measured at a calibrated orifice. The nozzle static pressure is set to about -28.5 cm (-11.2 in.) H_2O when operating on a plush carpet and to about -41.7 cm (-16.4 in.) H_2O on a level loop carpet.

Under these conditions the HVS2 has been shown to collect a consistent amount of the material on either carpet. With a standard test dust it will collect approximately 30% of the material in the test dust which was less than 150 um, in approximately equal quantities on either carpet. The variation in the collection efficiency of fine dust in repeat trials on carpets was 8% for level loop carpets and 12% for plush carpets. The variation as surface loadings were changed was of the same order.

The surface loadings reported are not corrected for these known recovery efficiencies as these are for standard test dusts and not house dust. The relationship between the recoverable rug dust loadings reported and the total dust or the dust effectively available to a crawling child is not known. However the consistency of the recovery with different loadings and different carpet materials makes the data a useful basis for future studies.

The recommended test procedures for the HVS2 (Roberts and Ruby, 1988) include calibration of the required measuring instruments, pretest preparation of the HVS2 and supplies, the procedures for sampling, and a procedure for clean-up in the field between samples. The sampling procedure calls for laying out eight 46 by 137 cm (18 by 54 in.) rectangles, setting the HVS2 flowrate and nozzle pressure drop, sampling four of these rectangles, and then continuing the sampling of the other four if less than 2 g of material has been collected.

To minimize the possibility of any loss of sample material or contamination, the sampling train is constructed of aluminum and stainless steel. The cyclone catch is collected in Teflon bottles. The quartz fiber filters (Pallflex, 2500 QAO or equal) are baked at 600 C for 2 hours. The PUF plug adsorbers were precleaned and supplied by Environmental Monitoring Services, Inc. and Southwest Research Institute.

SECTION 4

FIELD OPERATIONS

In addition to obtaining preliminary data on the amount and characteristics of dust in homes and preliminary data on the species and concentration of pesticides in house dust, this field study provided an opportunity to validate the High Volume Surface Sampler and to field test the sampling methodology. The latter included an evaluation of the practicality of the sampling, cleanup, and analysis procedures, the approximate times required to perform each of the tasks, a determination of the amount of sample that could be realistically collected in a normal range of houses, and an evaluation of the acceptability of the HVS2 by the residents of the sampled house.

Field operations can be divided into three elements: sample collection, sample processing, and sample documentation. The first includes operation and cleanup of the HVS2. The second includes sieving the collected dust to remove the large size fraction of the dust and preparation of the dust, filters and PUF plugs for shipment to an analytical laboratory. During the field study reported here an average of 1 hour was spent at each site for sample collection, which does not include the time spent by the NOPES project interviewer. An additional 1 hour was spent in cleanup and preparation of the HVS2 for the next sampling. Processing of the dust, filters, and PUF plugs and doing the necessary documentation took an additional 1.75 hours. Travel time to and from the sample site averaged 1 hour. Coordination with the NOPES project staff took an average of 0.5 hours per sample and unavoidable idle time amounted to about 1 hour per sample. Unpacking and initial setup of the field lab and the HVS2 took about 4 hours. Takedown and preparation for shipping at the end of the project took about 5 hours. This nine hour "overhead" would have to be repeated at each new city or major relocation of the operations base.

Sample Collection

A field lab was established in a motel room. The cleanup after the last sample each day, the preparation of samples for shipping to the analytical laboratory, and completion of all paperwork was done there. The assembled HVS2 was transported to the sampling sites in a station wagon.

Visits to sampling sites were scheduled by the NOPES support staff. In all but two cases the visits were concurrent with the removal of the ambient air sampling equipment and the final interview. Two to three visits were scheduled in one day, usually in the afternoon or evening.

Although the HVS2 weighs about 25 kg (55 pounds), it could be removed from the station wagon and carried into the house by one person. Two more trips were required to carry in the blower box, exhaust tubing, a collap-

sible sample area template, and a box of miscellaneous items (e.g., sample bottles, rubber stoppers, relative humidity gauge, tools, etc.).

Once in the house the floors were examined to locate areas where the 46 by 137 cm (18 by 54 in.) sample sections could be laid out. A folding frame was used as a template for marking the selected sampling areas with masking tape. Because the HVS2 overhangs the sampling area and some maneuvering room is required behind the sampled area, occasionally the marked sampling areas did not have sufficient clearance. It was sometimes necessary to move furniture to provide the needed clearance. The masking tape proved to be occasionally difficult to remove. Photographs of the HVS2 in use during this pilot study is provided in Figures 1 and 2.

It was necessary to use from 1 to 13 (average of 5) sampling areas to collect the required 2 g of sample. The sample areas contain 0.63 m^2 (6.8 ft^2). Because the amount of dust on the floor varied widely it was difficult to estimate prior to sampling how many sample areas would be required. The sampling continued over additional sample sections, which were in other rooms of the house in two samples (1064-014 and 1112-047), until about 2 g of material were collected. On average, this required less than 7 minutes. A top loader balance (accurate to 0.1 g) was used to check the weight of the cyclone catch cup. Even when 2 g of sample are collected, it is possible for less than the necessary amount of fine fraction to be available. Dust

Figure 1. Adjusting the HVS2 prior to sampling a home during the Jacksonville NOPES study.

Figure 2. Using the HVS2 during the Jacksonville NOPES study.

from one house (1112-047) was not submitted for analysis as less than 0.1 g of fine material was collected.

The length of time required to collect a sample can increase significantly if the house is clean. It took almost 1.5 hours to collect a 2 g sample in one house. The goal of a 2 g sample was originally established to permit bioassays of the sample as well as chemical analysis. It would be advisable to establish a sample size goal specific to the individual project, as this may permit a much smaller sample to be collected in a shorter time.

The baked, tared quartz fiber filter and tared Teflon cyclone catch bottle were put in place following each cleanup. For the first sample of the day, this had been done in the field lab. Glass fiber filters to be used for the second and subsequent samples were stored in aluminum foil rinsed with hexane before and after sampling. This and other steps that were necessary to prevent contamination were cumbersome and time consuming.

The PUF plug was removed from its protective shipping container and inserted into the HVS2 immediately prior to the beginning of sampling to minimize the possibility of field contamination. The glass cartridge holding the PUF plug was never handled directly; either fresh gloves were worn or only the aluminum foil wrap was handled. Even though the nominal diameters of the cartridges were all the same, four of the cartridges were too

large to fit into the holder on the HVS2. These PUF plugs had to be removed (with great care to avoid contamination) from their original cartridge and placed in another. The original PUF plug identifier was maintained for record-keeping purposes. Because of the problem with the cartridges no PUF plug adsorber sample was collected at one house (1227-216).

A leak check was made and the nozzle static pressure and flow rate were set for the type of carpet to be sampled. Leaks were observed during the leak check on several occasions. Leaks would occur if the clamps joining sections of tubing had not been tightened enough. Additionally, some of the gaskets seemed to expand with solvent which made it difficult to get a good fit soon after cleaning. If a leak was observed, the clamps were adjusted and the leak test repeated.

The sampling activities are intrusive. The noise of the blower motor for the HVS2 was significant even though the motor was enclosed in a box and the outlet muffled. Although the noise is no greater than most conventional vacuum cleaners, it is loud enough to disrupt a conversation carried on in a normal voice or to awaken a sleeping baby. Some concern was expressed about the exhaust from the blower motor, but an explanation about the HVS2 and how it actually removes contaminants from the air was always sufficient to answer the concerns. The power demand by the HVS2 did not prove to be a problem in any of the sample houses.

Because the amount of dust collected in the cyclone can be readily seen, there was some concern expressed by the residents about the sample team's evaluation of the relative cleanliness of their home. Thus it is important that all questionnaire activities be completed prior to the sampling to avoid any added incentive for the resident to distort information about cleaning activity.

After the sample was collected, the PUF plug was removed and returned to its shipping container. The container was stored in an ice chest packed with "dry" ice (solid CO_2). If the cleanup was performed in the field lab, the quartz fiber filter and cyclone cup were weighed immediately on removal and placed into shipping containers and stored on dry ice. If the cleanup was performed in the field the cyclone bottle was capped and the quartz fiber filter was placed in hexane rinsed, heavy aluminum foil and edges of the foil were double folded. Both were stored at ambient temperature until they could be weighed and the cyclone catch sieved.

The HVS2 was cleaned between runs using brushes and a mixed solvent (50% acetone/50% hexane) rinse on the entire sampling train between the nozzle and the PUF plug holder. Cleaning the HVS2 in the station wagon was difficult. The rear gate was used as a platform with the cleaning performed essentially in the open air. When the HVS2 was cleaned at the field lab it was again generally done outdoors, on the motel unit balcony. Either would have been impossible in the rain or a strong wind. The HVS2 must be kept dry, as water takes much too long to dry. If the interior surfaces of the HVS2 are wet, dust will stick to the wet area. In a strong wind, the components would be subject to contamination from wind-blown dust. In cold weather, the sampling personnel might be tempted to cut short the time necessary to do an adequate job of cleaning.

Cleaning in a confined space, even a motel room, presents potentially serious problems for exposure to the solvents. About 350 ml of the acetone/hexane cleaning solvent is used in a single cleanup of the HVS2. This much solvent fully evaporating into the average-sized motel room in one hour would easily exceed industrial hygiene exposure limits unless adequate ventilation is provided. If a container of solvents were spilled, the resulting air concentration could exceed the lower explosive limit. Because the venting of motel room exhaust fans is uncertain and the systems are not designed to handle chemicals they cannot be used to ventilate the room. A portable exhaust hood must be provided as cleaning in a confined space cannot be avoided during adverse weather conditions. An organic vapors protective mask should be provided for the sampling personnel as a further precaution.

The sampling experience under field conditions led to several suggestions for improvements in the design of the HVS2. The placement of the fan motor switch on the motor, rather than at the HVS2, was inconvenient. The size of the HVS2 makes it inconvenient in smaller rooms. A slight reduction in the width and length of the HVS2 would be possible without compromising the design and would make the unit more maneuverable. A change to smaller, longer, and more easily handled hoses would make the HVS2 more convenient to use and would allow the motor box to be placed either out-of-doors or in another room, which would reduce the noise and intrusiveness of the sampling.

Sample Processing

The cyclone catch was weighed and then separated into two size fractions, greater than and less than 150 um, using a shaker and sieves following ASTM standard method 422-63. The cyclone catch was not cooled prior to sieving to avoid any agglomeration caused by condensing moisture. To minimize any ageing of the sample, sieving was completed the same day the sample was collected. The fine fraction of the sample was wrapped in rinsed aluminum foil and stored in dry ice. The large-size fraction, which consisted primarily of hairs, fibers, and miscellaneous vegetable and mineral matter, was discarded. Large, granular pesticides and pesticide material adhered to pet hairs, carpet fibers, and similar large particulate matter, will be lost by this separation.

Cleanup of the sieves and the other implements and materials used in the separation required approximately 225 ml of acetone/hexane solvent. Similar problems with exposure to the solvent fumes described above occurred during cleanup after sieving.

The timing of the shaking may have had an influence on the amount of fines separated from the sample. A five minute shaking period was used, following the ASTM procedure. However, it is not clear that this is preferable to shaking to a constant weight of pan catch. Nor is it clear that the shaking does not break up the particulate matter, gradually producing more small particles. Further study will be necessary to determine if with house dust there is a marked difference between these two approaches.

The samples were labeled, packed in individual glass jars, and stored

in dry ice until shipment to the analytical laboratory by express courier.

Sample Documentation

The separated cyclone fines, the quartz fiber filter, and the PUF plug for each location were labeled with a unique number and recorded, along with all the rest of the data from that sampling site, on a sampling data sheet. A copy of the data sheet is provided in the appendix.

The data sheet recorded a variety of information about the sampling site and the collected samples. In addition to sample identification numbers, date, and time of sampling, the sheet provided a place to record information about the floor covering, ambient conditions at the time of sampling, and a sketch of the area sampled. Data on the sampling procedure were also recorded. All the steps in the processing of samples, from the tare weights to the final weights of the quartz fiber filters and the cyclone catch at each step of the separations, were recorded on the sheet.

One copy of the data sheet was signed and placed with the sample to serve as a chain-of-custody record. This copy was acknowledged by each person who handled the sample. The lab identification number was also entered on this sheet to provide a positive link between the sample and the final lab data reports.

A computer-based spreadsheet was prepared to receive, make the desired calculations, and present the data. The spreadsheet contained all the information from the sample data sheets and the pesticide values reported by the analytical laboratory.

SECTION 5

LABORATORY ANALYSIS

Weights of the fine fraction of the dust collected in the cyclone catch cup and on the quartz fiber filter were obtained at the field lab immediately after collection, as described above. Analysis for pesticide content in the dust, quartz fiber filter, and PUF plug was performed by Southwest Research Institute (SwRI).

Sample Extraction and Preparation

All extraction glassware was cleaned according to standard procedures for pesticide analysis, as detailed by Immerman et al. (1988b). The collected dust was extracted in a Soxhlet apparatus with 6% diethyl ether in hexane. The entire sample of cyclone fine fraction was placed in a filter, which was folded and placed in the extraction thimble. The quartz fiber filter and PUF plug were placed directly in the thimble. The dust and PUF samples were spiked with 120 ng of octachloronaphthalene to measure the relative recovery efficiency. The extraction continued for 16 hours at about 4 cycles per hour. The extract was concentrated in a Kuderna-Danish apparatus. Further information on the extraction procedure is provided by Immerman et al. (1988b).

Samples were held on dry ice until they could be extracted. All samples except one were extracted within 7 days. One combined cyclone catch-quartz fiber filter sample was held because of budget uncertainties and not extracted until the eighth day. Extracts were then refrigerated until they could be analyzed.

Analysis of Sample Extracts

Extracts were split into two aliquots for analysis by gas chromatograph with electron capture detection (GC/ECD) or mass spectroscopy (GC/MS). The GC/ECD procedure used two dissimilar megabore capillary columns, one for quantitation and one for confirmation. Details of the instrumentation and operating conditions for the GC/ECD are given in Table 3 and for the GC/MS in Table 4. GC/ECD was used to analyze for all but eight of the target pesticides, indicated in Table 5, which were analyzed by GC/MS. GC/MS was also used for secondary confirmation and quantification in support of the GC/ECD analysis. The analytical procedure was the same as for the NOPES air samples, which is described in detail by Immerman et al. (1988b).

In order to avoid false positive identifications, the GC/ECD retention windows were kept narrow, as small as 0.02 min for some compounds. To avoid false negatives, analyses with such small windows were manually screened to

TABLE 3. INSTRUMENTATION AND OPERATING CONDITIONS FOR GC/ECD ANALYSIS

	Quantitation	Confirmation
Instrument	HP 5890	HP5890
Column	OV-17	DB-5
Injector Temperature	235 C	235 C
Detector Temperature	350 C	350 C
Column Program	60 C for 2 mins to 140 C @25 C/min to 270 C @4 C/min	60 C for 2 mins to 140 C @25 C/min to 270 C @4 C/min
Carrier flow	10 mL/min	10 mL/min
Injector	Packed column	Grob-Splitless mode
Detector	ECD	ECD

determine if peaks present on the other column occurred adjacent to the window. All ECD target pesticides except chlordane were also checked by GC/MS, even though they were not primarily analyzed on the GC/MS. Specifically, gamma-BHC, chlorothalonil, heptachlor, chlorpyrifos, aldrin, DDT, DDD, and DDE were confirmed by GC/MS for several of the dust samples. The other NOPES target pesticides were confirmed by GC/MS for air samples during the Phase III analyses.

The values from the two GC/ECD columns were considered inconsistent when they differed by more than about a factor of two. In such cases, unless the larger value was supported by other evidence, the smaller value was reported. The larger value was assumed to be due to an interference.

Large amounts of pesticides in the dust samples caused a calibration drift problem in the GC/ECD OV-17 column during two analysis batches. The samples in these batches were diluted further and reanalyzed with a later batch. Drift was also observed in the captan standard during another batch. The samples affected by the calibration drift problems are noted in Table 10 where pesticide loadings and concentrations are reported.

The measured recovery efficiency of the octachloronaphthalene spike illustrates the difficulties experienced in working with the dust samples. The average recovery for indoor air samples in the homes sampled in this pilot study was 94% with a sample standard deviation (SD) of 7.6%. In

TABLE 4. INSTRUMENTATION AND OPERATING CONDITIONS FOR GC/MS ANALYSIS

Instrument	Finnigan 4600
Column	DB-5
Injector Temperature	245 C
Column Program	40 C for 2 mins to 295 C @10 C/min
Carrier flow	1 mL/min
Injector	Grob-Splitless mode
Electron energy	70 eV
Scan time	1 sec/scan
Detector	Multiple ion

contrast, the recovery for the cyclone dust samples averaged 80% with an SD of 44% and the recovery for the quartz fiber filter was 89% with an SD of 7%. Four of the dust samples required so much dilution before they could be measured that the spike was diluted below its detection limit. The data reported here are not adjusted for the varying spike recoveries.

The detection limits for GC/ECD were about 10 to 20 ng on the column per sample (cyclone dust, quartz fiber filter, or PUF plug adsorber) for most compounds, but about 100 ng on the column per sample for PCP, dicofol, cis- and trans-permethrin, and 2,4-D and about 200 ng per sample for dichlorvos. The GC/MS detection limits were about 50 to 75 ng per sample for six of the eight pesticides analyzed in this way, with ortho-phenylphenol having a limit of about 25 ng per sample and resmethrin a limit of about 125 ng per sample. These are translated into approximate equivalent minimum detection limits on a ng/m^3 basis for the indoor air samples and on a ng/m^2 basis for the surface dust samples in Table 5. The required minimum amount of pesticide on the column is adjusted for dilution and the air, dust, and area sampled. The limits are different for each house sampled because of the varying amounts of air, dust, or sample area in each sample.

The quantitation limits, a value which represents the lower limit of confident quantification measurement, are reported in Table 6. They are calculated in the same manner as the detection limits, but with a different amount of pesticide on the column. The detection and quantitation limits reported for dust represent the value for the cyclone catch, since this was the predominant portion of the total for most pesticides. The limits for the quartz fiber filter and the PUF plug adsorber generally were close to the value reported for the indoor air measurement.

The actual detection or quantitation limit for any given sample is dependent on a variety of factors, including the presence of interfering compounds. Precise values can only be determined by extensive and detailed study. The values given in Tables 5 and 6 are estimates and approximate.

TABLE 5. ESTIMATED DETECTION LIMITS FOR TARGET PESTICIDES

Household	1227-216		0753-039		1064-014		0490-026A		0490-026B		1440-016		1647-001		1064-011		0966-021		0782-038	
GC/ECD compounds	Air	Dust	Air	Dust	Air	Dust	Air	Dust	Air	Dust	Air	Dust	Air	Dust	Air	Dust	Air	Dust	Air	Dust
Dichlorvos	40	50	40	300	70	20	40	80	40	30	40	80	40	2000	40	26000	40	79000	40	320000
a-BHC	2	3	2	20	4	1	2	4	2	2	2	4	2	100	2	1000	2	4000	2	16000
HCB	2	3	2	20	4	1	2	4	2	2	2	4	2	100	2	1000	2	4000	2	16000
PCP	400	500	400	3000	700	200	400	800	400	300	400	800	400	20000	400	260000	400	790000	400	3200000
g-BHC	2	3	2	20	4	1	2	4	2	2	2	4	2	100	2	1000	2	4000	2	16000
Chlorothalonil	2	3	2	20	4	1	2	4	2	2	2	4	2	100	2	1000	2	4000	2	16000
Heptachlor	2	3	2	20	4	1	2	4	2	2	2	4	2	100	2	1000	2	4000	2	16000
Ronnel	2	3	2	20	4	1	2	4	2	2	2	4	2	100	2	1000	2	4000	2	16000
Chlorpyrifos	2	3	2	20	4	1	2	4	2	2	2	4	2	100	2	1000	2	4000	2	16000
Aldrin	2	3	2	20	4	1	2	4	2	2	2	4	2	100	2	1000	2	4000	2	16000
Dacthal	2	3	2	20	4	1	2	4	2	2	2	4	2	100	2	1000	2	4000	2	16000
Heptachlor epoxide	2	3	2	20	4	1	2	4	2	2	2	4	2	100	2	1000	2	4000	2	16000
Oxychlordane	2	3	2	20	4	1	2	4	2	2	2	4	2	100	2	1000	2	4000	2	16000
Captan	10	20	10	100	20	7	10	20	10	10	10	20	10	600	10	8000	10	24000	10	130000
Chlordane	10	20	20	100	30	10	20	30	20	10	20	30	20	800	20	11000	20	32000	10	130000
Folpet	7	10	8	60	10	5	8	20	8	7	8	20	8	400	9	5000	8	16000	7	64000
2,4 D	20	30	20	200	40	10	20	40	20	20	20	40	20	1000	20	13000	20	40000	20	160000
DDE	2	3	2	20	4	1	2	4	2	2	2	4	2	100	2	1000	2	4000	2	16000
Dieldrin	2	3	2	20	4	1	2	4	2	2	2	4	2	100	2	1000	2	4000	2	16000
DDT	2	3	2	20	4	1	2	4	2	2	2	4	2	100	2	1000	2	4000	2	16000
DDD	2	3	2	20	4	1	2	4	2	2	2	4	2	100	2	1000	2	4000	2	16000
Methoxychlor	2	3	2	20	4	1	2	4	2	2	2	4	2	100	2	1000	2	4000	2	16000
Dicofol	20	30	20	200	40	10	20	40	20	20	20	40	20	1000	20	13000	20	40000	20	160000
c-Permethrin	20	30	20	200	40	10	20	40	20	20	20	40	20	1000	20	13000	20	40000	20	160000
t-Permethrin	20	30	20	200	40	10	20	40	20	20	20	40	20	1000	20	13000	20	40000	20	160000
GC/MS Compounds																				
o-Phenylphenol	9	1000	9	2000	20	10	9	400	9	200	10	200	10	1000	10	13000	10	40000	9	160000
Propoxur	5	700	5	800	9	6	5	200	5	80	5	100	5	500	5	7000	5	20000	4	79000
Bendiocarb	10	2000	12	2000	20	20	10	500	10	200	10	200	10	1000	10	17000	10	50000	10	200000
Atrazine	10	2000	12	2000	20	20	10	500	10	200	10	200	10	1000	10	17000	10	50000	10	200000
Diazinon	10	2000	14	2000	30	20	10	600	10	200	20	300	20	1000	20	20000	20	60000	10	240000
Carbaryl	10	2000	12	2000	20	20	10	500	10	200	10	200	10	1000	10	17000	10	50000	10	200000
Malathion	10	2000	12	2000	20	20	10	500	10	200	10	200	10	1000	10	17000	10	50000	10	200000
Resmethrin	20	3000	24	4000	50	30	30	1000	30	400	30	500	30	2000	30	33000	30	99000	20	400000

Note: Air in ng/m3, dust in ng/m2
Compounds listed in order of elution from GC column

TABLE 6. QUANTITATION LIMITS FOR TARGET PESTICIDES.

Household	1227-216		0753-039		1064-014		0490-026A		0490-026B		1440-016		1647-001		1064-011		0966-021		0782-038	
	Air	Dust	Air	Dust	Air	Dust	Air	Dust	Air	Dust	Air	Dust	Air	Dust	Air	Dust	Air	Dust	Air	Dust
GC/ECD Compounds																				
Dichlorvos	360	530	380	3200	720	240	380	790	380	330	410	800	400	20000	440	265000	390	794000	360	3180000
a-BHC	7	11	8	63	14	5	8	16	8	7	8	16	8	400	9	5300	8	16000	7	63000
HCB	5	8	6	48	11	4	6	12	6	5	6	12	6	300	7	4000	6	12000	5	48000
PCP	720	1100	750	6300	1400	490	759	1600	760	670	810	1600	780	40000	870	529000	780	1590000	710	6350000
g-BHC	9	13	9	79	18	6	9	20	9	8	10	20	10	500	11	6600	10	20000	9	79000
Chlorothalonil	7	11	8	63	14	5	8	16	8	7	8	16	8	400	9	5300	8	16000	7	63000
Heptachlor	13	19	13	110	25	9	13	28	13	12	14	28	14	700	15	9300	14	28000	12	111000
Ronnel	13	19	13	110	25	9	13	28	13	12	14	28	14	700	15	9300	14	28000	12	111000
Chlorpyrifos	11	16	11	95	22	7	11	24	11	10	12	24	12	600	13	7900	12	24000	11	95000
Aldrin	9	13	9	79	18	6	9	20	9	8	10	20	10	500	11	6600	10	20000	9	79000
Dacthal	9	13	9	79	18	6	9	20	9	8	10	20	10	500	11	6600	10	20000	9	79000
Heptachlor epoxide	7	11	8	63	14	5	8	16	8	7	8	16	8	400	9	5300	8	16000	7	63000
Oxychlordane	11	16	11	95	22	7	11	24	11	10	12	24	12	600	13	7900	12	24000	11	95000
Captan	54	79	60	480	110	37	57	120	57	50	61	120	59	3000	65	40000	58	119000	53	476000
Chlordane	150	210	150	1300	290	98	152	320	150	130	160	320	160	8000	170	106000	160	317000	140	1270000
Folpet	36	53	40	317	72	24	38	79	38	33	40	79	39	2000	43	26000	39	79000	36	317000
2,4 D	180	270	190	1600	360	120	190	400	190	170	200	400	200	10000	220	132000	200	397000	180	1590000
DDE	11	16	11	95	22	7	11	24	11	10	12	24	12	600	13	8000	12	24000	11	95000
Dieldrin	14	21	15	130	29	10	15	32	15	13	16	32	16	800	17	11000	16	32000	14	127000
DDT	11	16	11	95	22	7	11	24	11	10	12	24	12	600	13	8000	12	24000	11	95000
DDD	11	16	11	95	22	7	11	24	11	10	12	24	12	600	13	8000	12	24000	11	95000
Methoxychlor	18	26	19	160	36	12	19	40	19	17	20	40	20	1000	22	13000	19	40000	18	159000
Dicofol	180	270	190	1600	360	120	190	400	190	170	200	400	200	10000	220	132000	190	397000	180	1590000
c-Permethrin	72	110	75	640	140	49	76	160	76	67	81	160	78	4000	87	53000	78	159000	71	635000
t-Permethrin	72	110	75	640	140	49	76	160	76	67	81	160	78	4000	87	53000	78	159000	71	635000
GC/MS Compounds																				
o-Phenylphenol	36	5300	38	6300	72	49	38	1600	38	670	40	800	39	4000	43	53000	39	159000	36	635000
Propoxur	18	2600	19	3200	36	24	19	790	19	330	20	400	20	2000	22	26000	19	79000	18	317000
Bendiocarb	45	6600	47	7900	90	61	47	2000	47	830	51	1000	49	5000	54	66000	49	198000	45	794000
Atrazine	45	6600	47	7900	90	61	47	2000	47	830	51	1000	49	5000	54	66000	49	198000	45	794000
Diazinon	54	7900	56	9500	100	73	57	2400	57	1000	61	1200	59	6000	65	79000	58	238000	53	952000
Carbaryl	45	6600	47	7900	90	61	47	2000	47	830	51	1000	49	5000	54	66000	49	198000	45	794000
Malathion	45	6600	47	7900	90	61	47	2000	47	830	51	1000	49	5000	54	66000	49	198000	45	794000
Resmethrin	90	13000	94	16000	180	120	95	4000	95	1700	101	2000	98	9900	109	132000	97	397000	89	158700

Note: Air in ng/m3, dust in ng/m2
Compounds listed in order of elution from GC column

SECTION 6

QUALITY CONTROL/ASSURANCE

Quality assurance objectives, separate from those used by NOPES for the laboratory analysis of samples, were not developed for this study. The elements of sample collection and analysis, other than the laboratory analysis, which could contribute to errors are the reproducibility of HVS2 sample collection efficiency, the operational settings and cleaning of the HVS2, the count and measurement of the areas sampled, the procedure for separating the fine fraction of the dust, the weighing of samples submitted to the laboratory, and the final data calculations. Although the HVS2 sample collection efficiency has been established for the two more common types of carpeting with a test dust, it has not been established for house dust (nor is house dust a single, consistent material). Quality control for the remaining elements is discussed in this section.

Quality Control/Assurance Activities

A performance audit on the sampling team procedures was conducted during a preliminary sample collection series prior to the Jacksonville field study. Use of the proper HVS2 settings and correct sampling and cleanup procedures was checked, as well as the leak check-corrective action cycle. Timers and magnehelics were checked for accuracy against transfer standards.

The top-loader balance used at the sampling site was periodically calibrated during the study with an external, Class P calibration weight. The analytical balance used in the field lab was calibrated with an internal NBS Class S calibration weight.

Sampling areas were established with a template rather than by measurement. The sample data sheet required both a count of the sample areas and a sketch of their location. The sheets were checked for consistency between these to data entries.

Data Validation

Data validation and editing of the participant questionnaires were carried out by the NOPES project staff and are described by Immerman et al. (1988b). Some of the same data (obtained by observation) were entered in the sample data sheet as comments by sampling personnel, and these entries were cross-checked against the questionnaire data.

Each of the analytical laboratory data reports was hand-checked and compared against the sample data sheet sample codes. Re-examination of two

data points was requested and changes were made by SwRI as a result. Further information on the validation procedures for the analytical laboratory data by SwRI is presented in Immerman et al. (1988b).

An audit was made of the underlying formulas in the spreadsheets used to analyze the data for this study.

Blank and Duplicate Samples

In addition to the internal laboratory blanks and duplicates, which are described and reported in Immerman et al. (1988b), one field blank and two field duplicates were submitted for analysis. The field blank was a PUF plug which was carried to one site (1227-216), opened, handled in the normal fashion, and returned to its shipping container. It was then re-opened at a second site (0782-038) and left sitting out during the entire sampling run before being returned to its shipping container. Both before and after the exposure, the PUF plug was handled as any other sample. The analysis of this PUF plug found none of the target pesticides.

Duplicate rug dust samples were collected at two sampling sites. Unfortunately, it is impossible to obtain true duplicate samples because the same physical area cannot be sampled a second time and an identical sample of dust collected. Instead, other areas in the same house were sampled. At site 0490-026, one rug was sampled in the bedroom and hallway leading to it and another rug was sampled in the living room and hallway near the front door . The first rug was of "plush" construction and the second was "level loop", a much tighter weave. The sample from the plush carpet required only 2.5 m^2 to collect the required 2 g sample, while the sample from the level loop carpet required 6 m^2. In addition, the plush carpet was almost new while the level loop carpet was approximately 18 years old. At site 1440-016, it was possible to set up a sampling area with alternate sections, as recommended by the HVS2 sampling procedure. However, even with the use of alternate sections there is still a variation possible in the expected dust loading. In this case one section of one set was directly in front of the front door.

The effects of these variations in anticipated dust loading can be seen in Table 7. In each case the sample which would be expected a priori to have the higher dust loading does, although at the second site the fine fractions are more nearly equal. This table also reports the surface concentration of pesticides at the two sites. The patterns of pesticides identified are similar between the replicates. At site 0490-026 there were 25 pesticides identified, with only 7 found in only one of the two samples, and in each case at relatively low concentrations. At site 1440-016 there were 15 pesticides identified, with only 5 found in only one of the samples.

The relative percent difference between the duplicates, where both samples have values for a given pesticide, can be expressed as RD = 200 x (S1-S2)/(S1+S2), where S1 and S2 are the two samples. The mean absolute value of the RD across the analytes for 0490-026 is 94.5%. The RD for 1440-016 is 69.9% for an average of the absolute value.

TABLE 7. DUPLICATE MEASUREMENTS OF DUST (g/m^2) AND PESTICIDES (ng/m^2)

Household	0490-026		1440-016	
Total dust loading	2.2	0.8	1.4	4.3
Dust <150 um loading	1.2	0.3	1.0	1.1
Dichlorvos	85			
o-Phenylphenol	203	433	171	233
Propoxur	276	160	167	698
Bendiocarb		4		
a-BHC	40	124		
HCB	4	5		
Atrazine	1111	167		
PCP		3017		
g-BHC	255	594	12	9
Diazinon	215	136	56	254
Chlorothalonil	213	1095	12	
Heptachlor	1894	3150	112	86
Carbaryl	1984	457		
Chlorpyrifos	5758	6947	260	357
Aldrin	12	226	13	
Dacthal		14		25
Heptachlor epoxide	43			
Captan	651	187		74
Chlordane	18206	31218	3655	7016
Folpet		70		
DDE	520	371	234	589
Dieldrin	414	5765	176	254
DDT	330	1263	27	405
DDD		372		
Methoxychlor	73	654		6

Note: Blanks indicate analytes not detected

SECTION 7

RESULTS

Sample Site Characteristics

Seven of the nine sample sites were single-family detached houses and the remaining two (1227-216 and 0782-038) were mobile homes. In all but one house (0782-038) most of the floors (other than kitchen and bathroom) were carpeted.

Seven of the nine sites used vacuum cleaners and six of those used an upright vacuum. One of the others volunteered that his vacuum cleaner was broken. Three of the households had cleaned the floors within the last three days and three more within the last week.

Sources of particulate matter included smokers in five of the houses and working fireplaces in three of the houses. Sampling personnel noted that at one house (1227-216) there was an unsurfaced dirt walkway to the house and that in one home (1064-014) the practice was to remove street shoes on entering the house.

The sample household characteristics are summarized in Table 8.

Dust Loading

The floor dust loadings at each site were determined by dividing the total sample collected in the cyclone and the fraction of that less than 150 um by the total area sampled. The results are presented in Table 9. The two houses which have the greatest loading are also the two houses which were not using a vacuum. The ratio of the fine fraction to the total dust load is about 0.5, if the two high loading houses are not included. At the site that was dropped from analysis (1112-047) because an inadequate amount of fine fraction was collected, the ratio of fine fraction to total cyclone catch was less than 0.04.

The dust loading at site 0782-038 was above the limits of the cyclone catch cup. As a result there was a spillover of dust to the quartz fiber filter. At the other sites, the mass on the quartz fiber filter ranged from 0.06% to 2.3% of the total mass less than 150 um. At this site the amount on the quartz fiber filter was over 6% of the cyclone fine fraction.

Pesticide Loadings and Concentrations in Air and Dust

The loading of the NOPES target pesticides was calculated by dividing the total mass of the pesticide (from the sum of pesticide collected in the

TABLE 8. CHARACTERISTICS OF SAMPLE HOUSEHOLDS

Household	1227 -216	0753 -039	1064 -014	0490 -026A	0490 -026B	1440 -016A	1440 -016B	1647 -001	1064 -011	0966 -021	0782 -038
Cleaning:Vacuumed/Swept	V	V	V	V	V	V	V	V	V	S	S
Upright or Cannister Vacuum	U	C	U	U	U	U	U	U	U		
Days since last cleaning	10	2	6	6	6	2	2	6	10	-	2
Packs of cigarettes per day	1	0	0	0	0	2	2	0.5	0	0	3
Fireplace use per month	0	0	0	0.75	0.75	0	0	0.75	0	0	0
Age of house (years)	2	41	25	48	48	23	23	21	13	29	20
Age of carpet (years)	2	15	2	1	18	7	7	2	2	20	3
Type of carpet	P	M	P	P	L	M	M	P	P	P	S
Area sampled (sq m)	3.8	3.2	8.2	2.5	6.0	2.5	2.5	5.0	1.9	1.3	0.6
Years since termiticide app		7		1	1	7	7			3	

Notes: Carpet type - P: Plush, M: Multi-level, L:Level loop, S:Shag

TABLE 9. TOTAL AND FINE FRACTION DUST LOADING BY HOUSEHOLD

Household	Total dust load (g/m^2)	Dust <150 um load (g/m^2)
1227-216	10.8	6.6
0753-039	4.2	3.0
1064-014	0.3	0.1
0490-026A	2.2	1.2
0490-026B	0.8	0.3
1440-016A	1.4	1.0
1440-016B	4.3	1.1
1647-001	0.8	0.3
1064-011	6.6	4.7
0966-021	33.7	23.3
0782-038	812.7	168.9

cyclone, on the quartz fiber filter, and on the PUF plug adsorber) by the area sampled. The concentration of the pesticide in the collected dust was calculated by dividing the total mass of pesticide by the mass of the fine fraction of the cyclone catch plus the mass on the quartz fiber filter. These results are presented in Table 10 for each household. Also shown on Table 10 are the concentrations measured in the indoor air at each site.

The data are reported as both a surface loading (ng/m^2) and as a concentration in the dust (ppb) as data have been reported by others using both measures. Previous work suggests surface loading may be better related to possible health effects. Davies et al. (1987) found a better correlation between lead surface loading and hand lead than between lead concentration in dust and hand lead.

As a point of comparison, other researchers have measured the surface loading of dichlorvos at about 50,000 ug/m^2 seven hours after a pesticide fogger was discharged in an average-sized (32.6 m^3 or 1150 ft^3) room (Maddy et al., 1981). They used a surface wipe procedure to measure the concentration on a smooth surface.

The correlation between the concentration (ppb) and pesticide loading (ng/m^2) measures was significant (at the 99% level) and robust for only two pesticides, chlorothalonil and g-BHC. For the remainder that could be statistically tested, the coefficients were also generally near zero.

The total pesticide loading on the floor is understated by these data. First, the large particle size fraction (>150 um diameter) was separated and was not submitted for analysis. Some pesticide materials may have been present in this segment of the floor dust. Second, the HVS2 does not collect 100% of the dust in a carpet. It is not known what fraction of the dust in the carpet is "available" for human uptake or how this relates to the fraction of dust which is collected by the HVS2. The HVS2 does collect a fraction which is approximately constant with loading and for different carpet materials.

An average of 7.5 target pesticides were identified in the indoor air

TABLE 10. CONCENTRATION OF PESTICIDES IN AIR AND SURFACE DUST

Household	1227-216			0753-039			1064-014			0490-026A			0490-0268		
	air	dust		air	dust		air	dust		air	dust		air	dust	
	ng/m3	ng/m2	ppb	ng/m3	ng/m2	ppb	ng/m3	ng/m2	ppb	ng/m3	ng/m2	ppb	ng/m3	ng/m2	ppb
Dichlorvos		399*	60*								85*	69*			
o-Phenylphenol	74	8730	1315		5778*	1896*		22*	360*		203*	165*		433	1368
Propoxur	156	13228	1992		2565*	842*	122	464	7600	17	276*	224*	17*	160*	505*
Bendiocarb														<40	<100
a-BHC				1*						32	40*	32*	32	124	391
HCB					21	7		1*	13*	4*	4*	3*	4	5*	14*
Atrazine											1111*	903*		167*	526*
PCP								1*	10*	68	255	207		3017	9526
g-BHC	27*	2646*	398*		22	7	133	635	10400	21	215*	175*	68	594	1876
Diazinon				57	17	5	7*	9	152	523	213*	173*	21*	136*	428*
Chlorothalonil								21*	340*		1984	1613	523	1095	3458
Carbaryl	4*	254	38	6*	249	82		13*	216*	684	1894	1540		457*	1443*
Heptachlor													684	3150	9947
Malathion	447	76190	11474	114	17851	5857	205	427	7000	870	5758	4681	870	6947	21937
Chlorpyrifos		3810	574		10	3		55	908		12*	10*		226	713
Aldrin								3*	50*					14	43
Dacthal											43	35			
Heptachlor epoxide										7			7*		
Oxychlordane								71	1170		651**	529**		187	589
Captan	31*	1812	273	75*	19550	6415	65*	225	3680	1710	18206	14800	1710	31218	98584
Chlordane										10			10*	70	220
Folpet										17			17*		
2,4 D					600	197		19	306		520	423		371	1173
DDE					1440	472	18*	32	524	49	414	336	49	5765	18205
Dieldrin		187	28	3*	4772**	1566**		4*	60*		330**	268**		1263	3988
DDT														372	1174
DDD					1005**	330**					73**	59**		654	2066
Methoxychlor															
c-Permethrin															
t-permethrin															

Notes: * Value less than defined quantitation limit. Value is more uncertain than others.
** Value is more uncertain than others due to continuing calibration drift.
< Pesticide confirmed as present in quartz fiber filter or PUF plug but not detected in cyclone due to high dilution required for analysis. Value shown is approximately detection limit of cyclone catch sample.
Blanks and analytes not listed are not detected or more properly "less than the detection limit" stated in Table 4.

TABLE 10. CONCENTRATION OF PESTICIDES IN AIR AND SURFACE DUST (cont'd)

Household	1440-016A			1440-0168			1647-001			1064-011			0966-021			0782-038		
	air	dust		air	dust		air	dust		air	dust		air	dust		air	dust	
	ng/m3	ng/m2	ppb	ng/m3	ng/m2	ppb	ng/m3	ng/m2	ppb	ng/m3	ng/m2	ppb	ng/m3	ng/m2	ppb	ng/m3	ng/m2	ppb
Dichlorvos																		
o-Phenylphenol	17*	171*	179*	17*	233*	210*	35*	<200	<800	15*	<7000	<1000	101	<32000	<1000			
Propoxur	65	167*	175*	65	698	629	82	<100	<500	17*			214	41540*	1786*	10*		
Bendiocarb	6*			6*														
a-BHC	4*			4*														
HCB								<20	<90									
Atrazine																		
PCP																		
g-BHC	11	12*	13*	11	9*	8*	3*											
Diazinon	32*	<200	<100	32*	254*	229*		<300	<1000	18*			31*	57413*	2469*	5*		
Chlorothalonil		12*	12*															
Carbaryl																		
Heptachlor	28	112	118	28	86	77	4*	<20	<100	2*	<9000	<2000		<39000	<2000			
Malathion	6*			6*							<700	<200	163	14729*	633*			
Chlorpyrifos	69	260	273	69	357	321	211	2073	8226	44	4431*	941*	62	59623	2564	40	193651	1147
Aldrin	24	13*	14*	24			35	263*	1045*		1390*	295*		7747*	333*		11270*	67*
Dacthal					25	22												
Heptachlor epoxide								36*	143*									
Oxychlordane																		
Captan					74**	67**												
Chlordane	314	3655	3838	314	7016	6314	30*	1167*	4630*	18*	12965*	2753*	222	<19000	<800			
Folpet														183894*	7908*	32*		
2,4 D																		
DDE		234	246		589	530												
Dieldrin	9*	176	185	9*	254	229	15*	352*	1398*		3672*	780*	10*	<3000	<100			
DDT		27	28		405	364								7433*	320*			
DDD														8990*	387*			
Methoxychlor					6*	6*												
c-Permethrin														5758*	248*			
t-Permethrin														21471*	923*			
														26254*	1129*			

Notes: * Value less than defined quantitation limit. Value is more uncertain than others.
** Value is more uncertain than others due to continuing calibration drift.
< Pesticide confirmed as present in quartz fiber filter or PUF plug but not detected in cyclone due to high dilution required for analysis. Value shown is approximately the detection limit of cyclone catch sample plus amount collected on quartz fiber filter and PUF plug filter.

Blanks and analytes not listed are not detected or more properly "less than the detection limit" stated in Table 4. Note that the detection limits for the four households on the right of the chart are much higher than the others due to necessary sample dilution.

TABLE 11. LOADING OF PESTICIDES (ng/m2) FOUND ONLY IN SURFACE DUST.

Household	1227-216	0753-039	1064-014	0490-026A	0490-026B	1440-016A	1440-016B	1647-001	1064-011	0966-021
Dichlorvos	399									
Atrazine			85							
PCP			1111	167						
Carbaryl				3017						
Dacthal		21	1984	457						
Heptachlor epoxide		3		14						
Captan			43			25		79	32	
DDE		71	651	187			36			
DDT	600	19	520	371	234	74				
DDD	4772	4	330	1263	27	589			47	
Methoxychlor				372		405			21	
c-Permethrin	1005		73	654					8990	
t-Permethrin						6			5758	
									21471	
									26254	

at the nine sites while an average of 11.8 pesticides were identified in the dust. The number observed in the floor dust ranged from 2 to 23. Thirteen pesticides were found only in the dust in these nine houses. These thirteen are listed with the loadings observed at each site in Table 11. Four of these (PCP, DDD, atrazine, and carbaryl) were not observed in indoor air in any of the samples taken during the Phase III Jacksonville segment of NOPES. In addition, six others (heptachlor epoxide, captan, methoxychlor, cis- and trans- permethrin, and DDT) were observed in indoor air of no more than four sites in the entire Jacksonville Phase III study. Conversely, of the six pesticides which were observed in samples from at least eight sites during this pilot study (heptachlor, chlorpyrifos, aldrin, dieldrin, chlordane, and ortho-phenylphenol), all but one were also observed in the air at most of those locations. The exception is aldrin, which was observed in the air at only two sites.

The relatively fewer number but higher loadings of pesticides observed in four of the households (1064-011, 0966-021, 0782-038, and to a lesser extent 1647-001) illustrates one of the more difficult problems in the analysis of such multi-component samples. In order to measure the maximum compound, it was necessary to dilute the extract to the point that the effective detection limit was raised above the expected values of many of the other compounds. This can be seen by comparing these sample sites to Table 5. Before such samples can be confidently analyzed for a broad spectrum of pesticides it will be necessary to develop a technique to remove the few highly concentrated pesticides from the cyclone catch extract.

Some of the pesticides were observed on the quartz fiber filter or the PUF plug in samples from these four households even though the compound was not reported in the (diluted) cyclone catch extract. The concentrations of these pesticides have been reported in Table 10 as less than the detection limit for the cyclone catch plus the observed value on the filters. This was not possible for site 0782-038 as the filter and cyclone catch were combined for analysis for budgetary reasons.

The sample here is too small for any statistical analyses which would be more broadly applicable. However a few simple tests were made to indicate the direction suggested by these data. First, a simple correlation was computed between the number of pesticides observed at each site and the questionnaire responses. No statistically significant correlations were found with any of the survey responses except for the age of the house. The (positive) correlation with this variable was highly significant (99% level) and was robust against the removal of individual data points.

Second, two simple checks were made of the relation between the observed air values and the observed dust values. One standard exploratory technique assigns the paired data points of the variable sets into a 2x2 contingency table according to the median values of the elements. If the resulting arrangement is unlikely to occur by chance, it is likely that with more data a relationship may be observed between the variables for many of the elements. In this case the pesticide measurements in the air and in the dust (with dust samples averaged for the two sites with duplicates) were arranged for air and dust values above or below the median value for that analyte across all sites. That is, data pairs where there was both a high value in the air and a high value in the dust (for that analyte) were

assigned to the same cell while the other combinations were assigned to their respective cells. Analytes at any site where values were not reported for both air and dust were excluded from consideration as were the values which were based on the detection limit of the cyclone catch. Of the 110 data points available, 47 were excluded (with 6 of those excluded because of the dilution of the cyclone catch). Of the data points used, only 13 represented data points where only air concentrations were measured while the rest were dust only values. In all, seven analytes could be used in this analysis.

When the dust values were expressed in concentration units (ppb) the null hypothesis that the sorting in the 2x2 table was due to chance could be rejected at the 99.9% confidence level. When the units were expressed as surface loading (ng/m^2), the null hypothesis could not be rejected at the 90% confidence level.

Another standard exploratory technique is to compute an average of the correlation coefficients for each of the elements in paired variable sets. Coefficients were calculated for the air-dust pairs for each of the seven analytes, again excluding the values where one on the pair was not detected or the value was based on the detection limit. When the dust data were expressed in concentration terms (ppb), all seven coefficients were positive and the average was very significantly different from 0. When the dust data were expressed in surface loading terms (ng/m^2) terms, two of the coefficients were negative and the average was not significantly different from 0.

Both of these exploratory tests suggest that further study with larger data sets is likely to find relationships between concentrations of pesticide in the air and concentrations in the dust but not with surface loading. However, the large number of data points which represent measurements only in the dust (over 45% of the data) suggests that for many analytes such relationships will not be found.

The NOPES inventory of pesticides present in the house found 27 different pesticide products present in the study houses. These pesticides contained at least 61 different active ingredients, of which 11 were NOPES target pesticides. The pesticides listed as in use at each site and the pesticides identified in the dust samples are shown in Table 12. With one exception, the pesticides which were not identified in the dust were from indoor use products and could reasonably be expected to be in the house if the products had actually been in use recently. The exception was the pesticides in the inventory but not identified in the sample at site 0966-021. These pesticides were all contained in a rose dust, which would have been used outside and would not have been used for at least four months at the time of sampling.

Distribution of Pesticides in the HVS2

The ability of the HVS2 to accurately collect a pesticide sample without the PUF plug was a significant research question examined during its initial laboratory evaluation and continued as an important objective during this field study. The pressure drop across the PUF plug adsorber at the high face velocity which is necessary for operation of the HVS2 places a

TABLE 12. PESTICIDES IN HOME INVENTORIES AND IDENTIFIED IN DUST SAMPLES

Household	1227 -216	0753 -039	1064 -014	0490 -026	1440 -016	1647 -001	1064 -011	0966 -021	0782 -038
Dichlorvos	S		I	S			I		
g-BHC			S						
Chlorpyrifos	S				S				
Diazinon	S								
Carbaryl		I		S				S	
Malathion						I		I	
Aldrin						S			
Chlordane				S					
Folpet								I	
Resmethrin		I							
Dicofol								I	

Note: I: in the inventory
S: in the inventory and identified in dust sample

severe design restriction on the HVS2. The use of a PUF pad as a lower pressure drop alternative to the plug was suggested during the earlier work, but was not explored.

In the laboratory study (Roberts and Ruby, 1988), diazinon, chlorpyrifos, and dieldrin were tested as illustrative of the range of pesticides that might be encountered in the field. In each of the laboratory tests , a dust was innoculated with the three pesticides, collected by the HVS2, and the HVS2 was then run for 8 minutes. In none of the tests was a significant amount of pesticide found on the PUF plug, even with concentrations in the dust as high as 20 ppm.

However, pesticides were found in the PUF plug in several of the samples collected in the field study. Table 13 provides an indication of the relative importance of the PUF plug by showing the percent error that would have occurred in reporting the loading or concentration in the dust at each site if the PUF plug had not been used.

Although the percent error without PUF plug was not significant for 20 of the pesticides detected, without it there would have been an average error ranging from 4 to 63 per cent for seven of the pesticides. However, only alpha-BHC was consistently found on the PUF plug when it was present in the sample. The other six pesticides were sometimes predominantly found in the PUF plug and in other houses the PUF plug contributed little or nothing to the total for that pesticide. For example, aldrin was found only on the PUF plug in three samples but in only insignificant amounts or not at all in six samples. Similarly, heptachlor was found on the PUF plug in significant amounts in five samples but in small amounts or not at all in four samples.

It is not clear if the compounds collected in the PUF plug adsorber come from the ambient air drawn through the HVS2 or from pesticide material stripped off the particles in the cyclone and on the quartz fiber filter. The ambient air drawn through the HVS2 must be first drawn through a carpet which can be assumed to be a very effective particle filter and possibly an

TABLE 13. PERCENT ERROR IN ESTIMATING DUST CONCENTRATION WITHOUT INCLUDING PUF PLUG

Household	0753 -039	1064 -014	0490 -026A	0490 -026B	1440 -016A	1440 -016B	1647 -001	1064 -011	0966 -021	0782 -038	Avg
Dichlorvos			0								0
o-Phenylphenol	0	0	0	11	26	0	0	0	0		4
Propoxur	0	0	0	0	0	0	0		0		0
Bendiocarb				0							0
a-BHC			77	36							57
HCB	15	100	0	100			100				63
Atrazine			0	0							0
PCP				0							0
g-BHC		100	9	20	60	0					38
Diazinon	0	0	0	0	0	0	0		0		0
Chlorothalonil	0	0	0	0	0						0
Carbaryl		0	0	0				0	0		0
Heptachlor	7	81	39	30	63	0	<62	0	0		<31
Chlorpyrifos	0	0	0	0	0	0	0	0	0	0	0
Aldrin	100	0	100	3	100		3	0	0	0	34
Dacthal		0		0		0					0
Heptachlor epoxide			0				0				0
Captan		0	0	0		0			<100		<20
Chlordane	0	0	0	0	0	0	1	0	0		0
Folpet				0							0
DDE	0	0	0	0	0	0			0		0
Dieldrin	0	0	0	0	0	0	0	0	0		0
DDT	0	0	0	0	0	0			0		0
DDD				0							0
Methoxychlor	0		0	0		0			0		0
c-Permethrin									0		0
t-Permethrin									0		0

Note: < Pesticide was not detected in cyclone due to high dilution required for analysis. Value shown assumes 0 in cyclone.

effective adsorber for vapors. Particles from the air filtered in the carpet may be collected by the HVS2 as it makes a total of eight passes over the area.

It is doubtful that much of the pesticide in the air exists in airborne particles. A quick calculation will show that with any average concentration of suspended fine particulate matter in the indoor air (say 30 ug/m^3), the concentration of pesticides in the dust can account for only a small portion of the measured air concentrations unless the concentration in the dust is extremely high. Thus it is generally assumed that most of the pesticides are in the vapor phase. These pesticides must then either be adsorbed onto the carpet fibers, onto particles on the filter, or collected on the PUF plug.

Conversely, pesticides on particles on the quartz fiber filter could be removed to be captured by the PUF plug adsorber, even though the sampling period is short (from 2 to 20 minutes). Previous work (Bidleman et al., 1986) has established that pesticides with higher vapor pressure will tend to partition more to the vapor phase, and thus could be expected to diffuse to the lower concentration state in the air flowing through the filter.

Table 14 provides a summary of where in the HVS2 each of the pesticides that was found in seven or more samples (data with a high detection limit in the cyclone catch were excluded) is likely to be collected (in the cyclone,

TABLE 14. DISTRIBUTION OF PESTICIDES AMONG THREE COLLECTION POINTS IN HVS2.

	Vapor Pressure	Cyclone Catch	Quartz Fiber	PUF Plug
o-Phenylphenol	1.7 E-2	79.6% (16.6)	13.4% (8.2)	7.3% (10.1)
Propoxur	6.5 E-6	74.2% (32.7)	25.8% (32.7)	0%
Diazinon	1.4 E-4	71.9% (36.4)	28.1% (36.4)	0%
Heptachlor	3 E-4	68.6% (25.9)	8.2% (5.9)	23.2% (23.3)
Chlorpyrifos	1.9 E-5 @ 25 C	89.2% (13.2)	10.8% (13.2)	0.01% (0.03)
Aldrin	6 E-6	55.3% (48.0)	1.0% (1.9)	43.7% (47.8)
Chlordane	1 E-5	92.7% (6.9)	7.2% (7.2)	0.2% (0.4)
DDE	6.5 E-6	96.8% (3.1)	3.2% (3.1)	0%
Dieldrin	1.8 E-7	92.3% (9.1)	7.7% (9.1)	0%
DDT	1.9 E-7	98.8% (2.4)	1.2% (2.4)	0%

Notes: Vapor pressure in mm Hg @ 20 C unless otherwise noted.
The sample standard deviation is shown in parenthesis.

on the quartz fiber filter, or in the PUF plug adsorber). The sample standard deviation is also shown (in parenthesis).

Table 14 also lists the vapor pressure of each of these pesticides. However, Bidleman et al. (1986) have shown that polarity and shape are also important factors. All three variables play a role in determining the order compounds will elute from a gas chromatograph column. Following this logic, the compounds in the tables are listed, from top to bottom, in the order they elute from the DB-5 GC column. The trend in the table, from top to bottom, suggests this as a partial explanation, but the anomalous behavior of several compounds points out the importance of other, unknown, factors.

If we compare the amount of pesticide potentially available in the air drawn through the HVS2 with the amount extracted from the PUF plug and quartz fiber filter we find there is generally much more pesticide in the air than is present in the filter or PUF plug. If we exclude from analysis the three sites where the quartz fiber filter was extracted with the cyclone catch or there was no PUF plug used, we find 18 cases where there is none of a pesticide found on either the filters or the PUF plug even though that pesticide was measured in the air. In 53 additional cases the mass that potentially could have been in the air volume sampled exceeded the mass measured on the PUF plug and in half of those cases it exceeded the mass on both the PUF plug and the filter. In 29 cases the potential pesticide mass in the air was less than the amount measured on both the filter and PUF plug and in 6 cases it was less than that measured on only the PUF plug. Of these 6 cases, 4 involve the two pesticides with high percentages found on the PUF plug in Table 14.

To better understand the removal of pesticides from particulate matter by the action of air blowing through a quartz fiber filter, a small experiment was run in conjunction with this pilot study. A test dust was innoculated with three pesticides and applied to the HVS2, in the same manner as the pesticide experiments described by Roberts and Ruby (1988). The cyclone catch cup was removed after 8 minutes and replaced by a clean cup (so the cup would not act as a continuing source of pesticides). The HVS2 was then run for 2, 4.5, or 8 hours at 9.5 L/s (20 cfm). The filters were analyzed at 8 minutes and each of the other three time periods in the same manner as described by Roberts and Ruby (1988). If the pesticides were being transferred to the moving air stream, the concentration on the filter should decline with time.

The results are shown in Table 15. The concentrations for each pesticide are expressed as self-consistent ratios since the amount of pesticide

TABLE 15. RELATIVE CONCENTRATION OF PESTICIDES ON FILTER WITH TIME

	Vapor Pressure	2 hours	4.5 hours	8 hours
PCP	1 E-3	1.53	0.23	0.15
Chlorpyrifos	1.9 E-5	3.37	1.11	0.14
Dieldrin	1.8 E-7	3.83	1.34	0.17

Notes: Vapor pressure is expressed in mm Hg. Pesticide concentrations are self-consistent unitless ratios.

in the initial dust was different in each of the experiments. The pesticides were selected from early, middle, and late eluting compounds (with the additional requirement that they be easily identified by GC/ECD). The decline in the concentration for chlorpyrifos and dieldrin are approximately logarithmic while the decline of the PCP concentration is faster than logarithmic.

This experiment suggests that blowoff from pesticides on particulate matter could be an important source of the pesticide in a backup PUF plug adsorber. It further suggests that for short-term sampling it will be, in part, dependent on the vapor pressure of the pesticide but for long-term sampling (e.g., 24-hours) the vapor pressure will be much less important as a substantial part of the pesticide will be removed from the particulate matter.

SECTION 8

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APPENDIX A

HVS2 SAMPLING DATA SHEET

HIGH VOLUME SURFACE SAMPLING DATA SHEET

Reference # for sampling Location: Month-Day-Sequence # _____
Sampling Period __ __ PUF LOT # or SOURCE:_____

RTI Household ID __ __ __ __ - __ __ __

Date:_____ Time of Start:_____ End:_____

TYPE OF SURFACE: Rug___ Bare Floor___ Other_____ Age of Rug ___
TYPE OF RUG: Plush___ Level Loop___ Flat___ Multilevel___ Shag___
Temp:_____F ; Relative Humidity _____%
Location of area sampled:_____
Area Sampled:_____Sections or _____ sq.meters.
Sketch area sampled:

Leak Check:_____delta P
Sampling Time:_____ minutes _____sec. Flow Rate_____cfm____del
Filter and Sample: Wt. _____ Filter Alone _____
Net weight of Particulate collected on filter:_____
Filter Reference #: Month-Day-Sequence _____

Wt. of Cyclone jar and catch:_____ Wt. of Jar_____
Net weight of Cyclone catch: _____
Cyclone jar reference #: Month-Day-Sequence _____
Net weight less than 100 mesh: _____
Weight less than 100 mesh plus filter particulate weight:_____

Wt on surface: Wt/area_____= _____ grams/m2

Comments:_____
_____
_____
_____

Sample ID #			Check which
Filter	__ __ - __ __ -	__ __ __ __ - __ __ __	
Cyclone	__ __ - __ __ -	__ __ __ __ - __ __ __	___
Combined Fil+Cycl	__ __ - __ __ -	__ __ __ __ - __ __ __	___
polyUrethane Plug	__ __ - __ __ -	__ __ __ __ - __ __ __	___
Sample Collected by:		_____	___

Laboratory Receipt Date:_____ Sample Shipment Date:_____
Logged in by:_____

Lab Sample #:(__ __) - __ __ - __ __

	ORIGINAL WT.	WT. AFTER SIEVING	NET WT.
LID			
#50			
#100			
PAN			

TOTAL NET WT. _____

WEIGHT OF THE CYCLONE BEFORE: _____

WEIGHT OF THE CYCLONE AFTER: _____

The samples from the HVS2 will be:

C - for Cyclone catch (dust)

F - for the Filter

B - for Both cyclone and filter

U - for polyUrethane foam

The Sampling Event will be:

H - House dust sampling

B - field Blank

D - Duplicate

APPENDIX B

HVS2 SAMPLE QUESTIONNAIRE

HIGH VOLUME SURFACE

SAMPLE QUESTIONNAIRE

SEGMENT NO: ☐☐☐☐

SHU NO: ☐☐☐

PERSON NO: ☐☐

1. In the floor area we will be working, how are the floors generally cleaned? (For example, swept, vacuumed, or mopped?)

   a. ☐ Swept

   b. ☐ Vacuumed

   c. ☐ Mopped

   d. ☐ Other (specify) _____

2. Is a vacuum ever used to clean this household?

   a. ☐ Yes

   b. ☐ No (GO TO QUESTION 4)

3. What type of vacuum is used to clean this household? (CHECK ALL THAT APPLY.)

   a. ☐ Upright

   b. ☐ Cannister with powerhead

   c. ☐ Cannister without powerhead

   d. ☐ Electric Broom

   e. ☐ Other (specify) _____

4. When was the last time the area we will be working in was generally cleaned?

a. ☐ 1 - 3 days ago

b. ☐ 4 - 7 days ago

c. ☐ 8 - 14 days ago

d. ☐ >14 days ago

e. ☐ Other (specify) _____

5. Does anyone ever smoke cigarettes in this household?

a. ☐ Yes

b. ☐ No (GO TO QUESTION 7)

6. APPROXIMATELY HOW MANY PACKS a day are smoked in this household?

a. ☐ <1/2 pack

b. ☐ 1/2 pack to 1 pack

c. ☐ 1 pack to 2 packs

d. ☐ >2 packs

e. ☐ Other (specify) _____

7. Does this household have a working fireplace or woodstove?

a. ☐ Yes

b ☐ No (END OF INTERVIEW)

8. During this season, how frequently is the fireplace or woodstove used?

# of Times ☐☐ per ☐ Week

☐ Month

Other (specify) _____